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AN EXTENSOMETER FOR CIRCUMFERENTIAL STRAINS

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by

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Measurement of circumferential strains in thin-walled tubular specimens with high sensitivity presents difficulties for any material, but especially so for plastics. Strain gages are not satisfactory for two reasons: the local stiffening caused by application of the strain gage and the local heating resulting from the current in the gage [1]**. Capacitance type instruments which utilize the specimen as one leaf of the capacitor are not suitable because of the low conductivity of plastics. Metal plating of the surface might solve this problem except that deformation of the specimen would make continuity of the metallic film uncertain. Use of a wrap-around tape to measure changes in circumference was found to involve too much friction.

The instrument described in this paper was designed to avoid some of the above problems. The method consists of probing the position of the surface of the specimen at opposite ends of two mutually perpendicular diameters, and averaging the change indicated in the two diameters. This method partially accounts for the possibility that the specimen may change shape of cross-section as well as diameter. It does not of course account for all possible shape changes. A further refinement is to probe the surface at the ends of three diameters located 120° apart.

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** Numbers in brackets indicate references at the end of this paper.

Sensor: The probing was accomplished by mounting two pairs of sensors on an invar ring, A Fig. 1, so that modest changes in temperature would not give false indications of strain. The sensors consisted of 6 volt direct-current differential transformers (DCDTs), Sanborn Model (CT8-050-B2) having ±0.05 in. range, B Fig. 1. These sensors were equipped with jeweled bearings to guide the cores so that lateral motion of the cores was prevented and so that axial motion involved a minimum of friction. Hand selection of bearings to achieve minimum clearance was required for satisfactory performance. The DCDT's were also provided with springs so that the probe was held in contact with the specimen surface by a force of 10 grams. A pair of threaded rings on the case of the DCDTs permitted adjustment of axial position.

Each pair of DCDTs were mounted co-axially on opposite sides of the invar ring so as to measure changes in diameter. They were wired so as to add the output of a pair. Thus, the output of the pair indicated changes in diameter but was insensitive to translation of the invar ring with respect to the specimen. The output of each pair could be recorded separately or summed.

Mounting of the invar ring required special attention to avoid constraints which might distort the ring and to minimize sliding of the probes along the specimen surface during experiments. To accomplish these objectives the ring was supported freely on a tripod, C Fig. 1, consisting of three adjustable screws which were mounted in a bracket clamped to the lower grip holding the specimen. The axis of the specimen was of course vertical. The position at which the four probes contacted the specimen was made near the lower end of the specimen gage length and the mounting for the invar ring was at the lower grip of the specimen. Thus the amount of relative movement of the probe points over the specimen surface was minimized. Also the ends of the probes

had a radius of 0.02 in.. No effect of surface roughness on creep measurements was observed.

An alternate mounting which was found satisfactory was to fasten the invar ring at one point only rigidly to the lower grip of the specimen. This method requires a mounting of sufficient rigidity to avoid vibration.

The invar ring was split into two halves for assembly after the specimen was installed. Light gage flexible wire was employed for leads to the DCDTs to minimize mechanical disturbances. The wire used was Tensolite - No. 1482A-1 consisting of six strands 0.0035 in. dia. in vinyl insulation 0.03 in. outside diameter. A generous loop of wire was allowed between a fixed support on the machine and a fixed support on the invar ring.

<u>Read-Out, Calibration and Stability</u>: The regulated power supply for the DCDT was provided by Sanborn TPS11 and Multiple DCDT Power Supply Adaptor T41-11. A precision five-digit voltage supply (Digitran Switch Model - K035-0004) was employed as the voltage standard in the circuit shown in Fig. 2 to buck the voltage from each pair of DCDTs. This instrument was adjusted until its voltage balanced that from the pair of DCDTs. The reading of the voltage supply indicator was then equal to the output of the DCDTs. The null balance point was indicated by a vacuum tube voltmeter.

With this system a sensitivity of 0.1 MV was obtained for the transverse strain measurement. This corresponds to a sensitivity of 4×10^{-6} in./in.. The system described above was found to yield a greater sensitivity in the low range than measuring the voltage output of the DCDTs directly with a digital voltmeter.

Calibration was accomplished by measuring the output of each DCDT against a Pratt and Whitney precision micrometer. The regulated power supply

was provided with a separate sensitivity adjustment for each DCDT. Thus, it was possible to match the output of the four DCDTs within 0.5 percent. The average output of the four DCDTs represented the average radial displacement u. From this the circumferential strain ε_θ is given by

$$\varepsilon_\theta = \frac{u}{b} ,$$

where b is the radius of the outside surface of the tube. For the system employed the calibration indicated that 1 MV equaled 36×10^{-6} in./in. for a one inch O.D. tube.

The stability of the system was checked by mounting the instrument with an invar rod in place of the specimen and recording the output over 120 hrs. with the instrument located in a room maintained at a constant temperature of 75 ±1/2°F. The observed changes were very small: ±0.15 and ±0.10 MV respectively for the two pairs of DCDTs.

Example of Performance: Creep of a thin-walled tube of polyurethane plastic under axial compression and/or internal pressure was measured. Circumferential strains determined with the instrument described are shown in Fig. 3 for three tests. The compression apparatus was described in [2] and the axial extensometer was similar to that described in [3]. Axial creep during one of the tests is also shown in Fig. 3. The scatter of observations for similar magnitudes of strain is about the same for circumferential strain as for axial strain.

Acknowledgment

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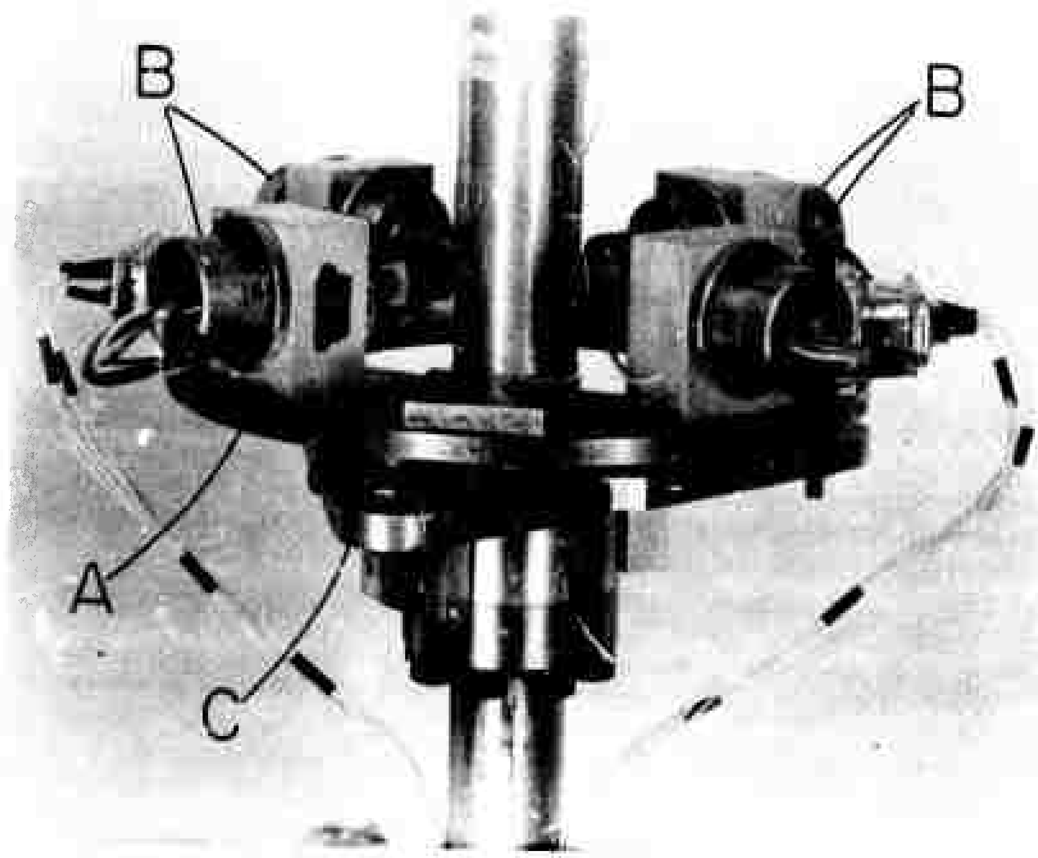

Figure 1. Circumferential Extensometer Mounted on Aluminum Specimen.

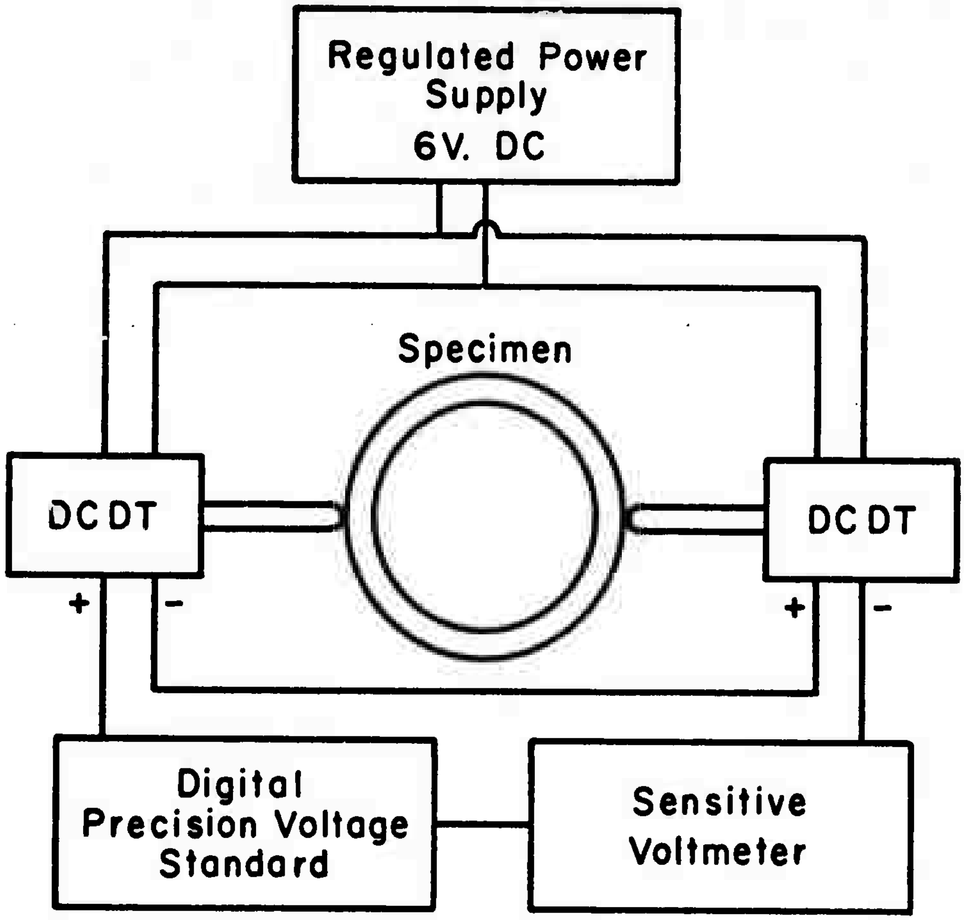

Figure 2. Wiring Diagram for One Pair of Direct Current Differential Transformers.

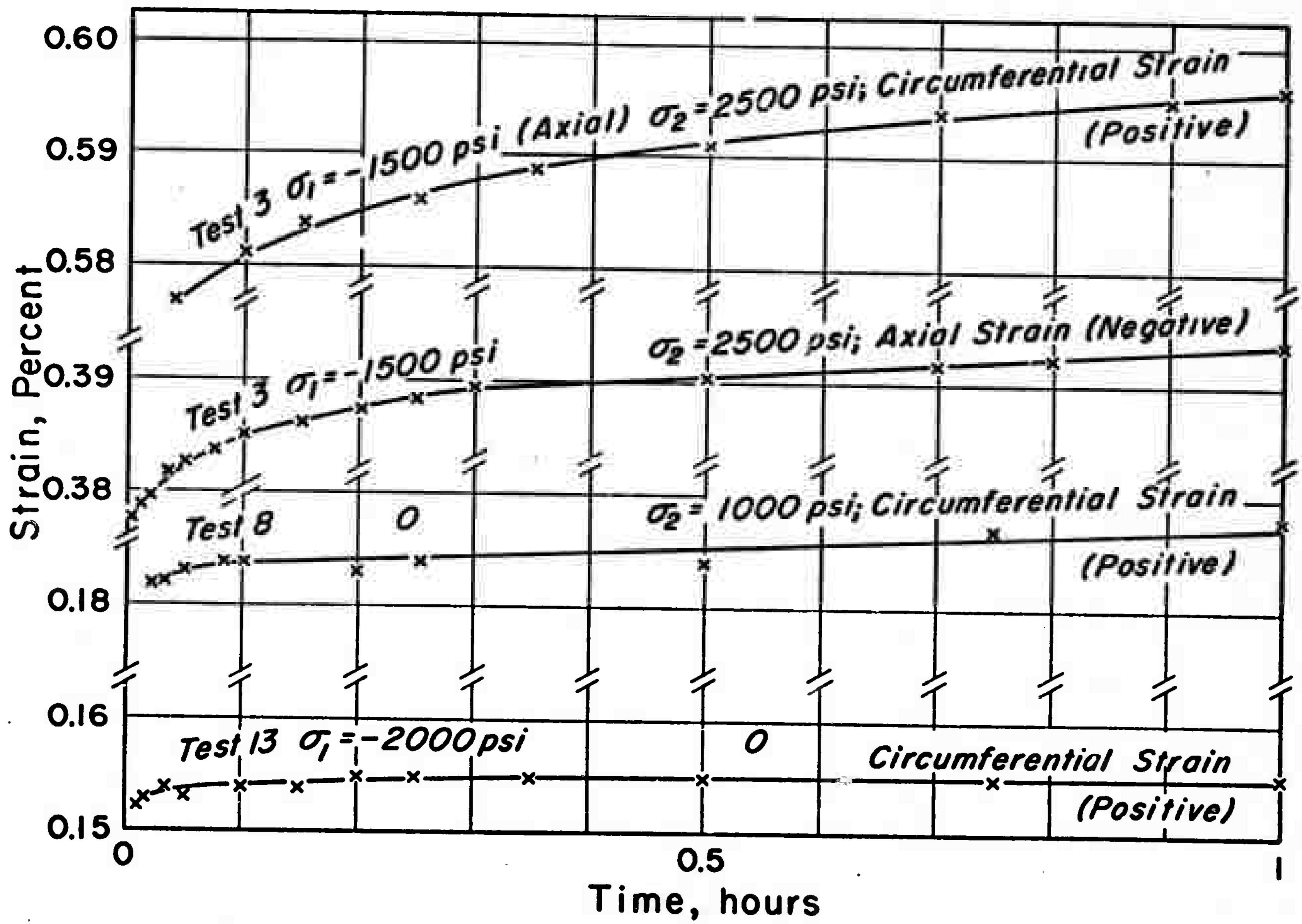

Figure 3. Creep Curves for a Full Density Polyurethane Tubular Specimen Tested under Axial Compression and Internal Pressure at 75°F and 50 per cent Relative Humidity.